5 COLORIMETRY

5.1 Introduction to Color

5.1.1 Objectives

Through completion of this module the trainee will develop the theoretical knowledge to be conversant in:

- Color/colorimetry definitions, terminology and theory.

5.1.2 Required Readings

5.1.2.1 Minolta publication PCC 410-B2, Precise Color Communication, Minolta Camera Co., Ltd., Japan, no date.

5.1.2.2 HunterLab publication GC 2.0.1, 11/90, The Science and Technology of Appearance Measurement.

5.1.2.3 HunterLab publication GC 2.2 8.5K, 8/87, Analyzing Appearance by Measurements.

5.1.3 Questions

The trainee will provide written answers to the following questions:

- Briefly describe the following in layman's terms:
  - Visual and instrumental color
  - Reflected, transmitted and scattered light
  - Primary colors
  - Light source, sample/standard and observer/instrument
  - Hue, Value and Chroma and equivalent terminology

5.1.4 Practical Exercise

5.1.4.1 The trainee will make and explain a color wheel diagram.

5.1.5 Evaluation

5.1.5.1 The trainer will review the written answers to the questions with the trainee.

5.1.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

5.1.5.3 Review of practical exercise.

5.1.5.3 The trainee will be quizzed orally upon the subject matter.

5.2 Introduction to Colorimetry

5.2.1 Objectives

Through completion of this module the trainee will develop the theoretical knowledge to be conversant in:

- Color classification and measurement systems

5.2.2 Required Readings

5.2.2.1 Billmeyer, Fred W., Jr., and Saltzman, Max, Principles of Color Technology, 2nd ed., New York, New York, John Wiley and Sons, 1981, Chapters 1 and 2.

5.2.2.2 Cousins, D. R., "The Use of Microspectrophotometry in the Examination of Paints", Forensic Science Review, Vol. 1, No. 2, Dec. 1989, pp.142-162.

5.2.2.3 Fouweather, C., May, R.W., and Porter, J., "The Application of a Standard Color Coding System to Paint in Forensic Science", Journal of Forensic Sciences, Vol. 21, 1976, pp. 629-635.

5.2.2.4 Locke, J., Cousins, D. R., Russell, L. W., Jenkins, C. M., and Wilkinson, J. M., "A Data Collection of Vehicle Topcoat Colours. 1. Instrumentation for Colour Measurements", Forensic Science International, Vol. 34, 1987, pp.131-142.

5.2.2.5 Macbeth brochure, "SpectraLight® Color Matching Booths and Luminaries," no date.

5.2.2.6 Willard, Hobart H., Merritt, Lynne L., Dean, John A., and Settle, Frank A., Jr., Instrumental Methods of Analysis, 6th ed., Wadsworth Publishing Company, Belmont, CA, 1981, pp. 1-4.

5.2.3 Questions

The trainee will provide written answers to the following questions:

- List and describe the three things required to produce color (from a purely physical point of view)
- As compared with daylight, what part of the visible spectrum is skewed with typical incandescent lighting? Florescent lighting?
- Concisely describe the following:
  - Metamerism
  - Refraction
  - Types of standard source lighting
  - CIE Standard Observer
  - 2 degree field of vision
  - Color Systems (CIE Yxy, L*a*b* and Munsell)
  - Absolute or difference color measurements; which tends to be more accurate?
  - Opponent type color system

5.2.4 Practical Exercises

5.2.4.1 The trainee will view the samples in the Macbeth Daylighting Metamerism Test Kits #2 and #3 and record their observations.

5.2.4.2 The trainee will draw a wavelength (nm) scale showing electromagnetic radiation.

5.2.5 Evaluation

5.2.5.1 The trainer will review the written answers to the questions with the trainee.

5.2.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

5.2.5.3 Review of practical exercises.

5.2.5.4 The trainee will be quizzed orally upon the subject matter.

5.3 Munsell Color System

5.3.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Describe the Munsell Color System and the Munsell Book of Color; and
- Visually and/or microscopically determine the location/closest match of samples within the Munsell Book of Color.

5.3.2 Required Readings

5.3.2.1 Macbeth/Munsell publication 7m JUL 90, Munsell Color (Munsell Color Space)

5.3.2.2 Macbeth/Munsell written pages in the front of the R-G volume of the Munsell Book of Color (Glossy Finish Collection Removable Samples in Two Binders), Macbeth Division of Kollmorgen Instruments Corporation, Baltimore, Maryland.

5.3.3 Questions

The trainee will provide written answers to the following questions:

- The approximate spacing of color chips is based upon what criteria in the Munsell system?
- Approximately, how many color chips are in the Munsell Glossy Book of Color?
- What are the end points that limit the "value scale"?
- What are the tolerances for the color standards?
- How could the Munsell Book of Color be useful in a hit and run case?

5.3.4 Practical Exercises

5.3.4.1 The trainee will physically study the Book of Color as a 3D color tree to familiarize the trainee with the 3D format.

5.3.4.2 The trainee will select at least two objects of each color: nonmetallic red, green, and blue and will determine their approximate color location in the Munsell Book of Color (unaided eye, 15 minutes total time). Find two other examiners to do the same. Record all results.

5.3.4.3 The trainee will be given test sample #1 which consists of a minute paint particle removed from a pedestrian's clothing in a hit and run case (no suspect vehicle). Examine this sample with the stereomicroscope in the presence of the trainer. Immediately afterwards, find a Munsell Book of Color chip that you feel is close to your sample (unaided eye, without looking at your sample again). Based solely upon these observations, describe the color to the trainer. Repeat above and find the best match in the Munsell Book of Color using your stereoscope and side-by-side comparisons. Record your results.

5.3.5 Evaluation

5.3.5.1 The trainer will review the written answers to the questions with the trainee.

5.3.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

5.3.5.3 Review of practical exercises.

5.4 Minolta Chroma Meter CR-221 (Colorimeter)

5.4.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Describe the basic capabilities and operation of the CR-22 Colorimeter;
- Understand the specific operational procedures and uses in the Trace Evidence Section;
- Determine the suitability of samples for Colorimetry comparisons;
- Prepare routine and non-routine samples; and
- Interpret data and provide instrument support report summaries.

5.4.2 Required Readings

5.4.2.1 Minolta Operators Manual, CHROMA METER CR-200 CR-231 with CHROMA METER CR-221 supplement including insert "SHORT FORM INSTRUCTIONS FOR **NEW** DATA PROCESSOR", Minolta Camera Co., Ltd., Japan, 1987. **Caution!! Do not follow this instruction unless a new instrument is being set up since it will wipe out all calibration target values that are stored in the memory**.

5.4.2.2 Smith, Douglas B., "The Minolta CR-21 Chroma Meter and Color Theory: Applications in Paint Analysis for Forensic Casework", Independent Study Forensic Master's Program, Virginia Commonwealth University, 1989.

5.4.3 Questions

The trainee will provide written answers to the following questions:

- List the properties that samples must have to be suitable for comparison.
- What do you think are the top 3 deficiencies that make paint samples unsuitable for comparison?
- What are the three filters used in the instrument? What are the primary colors used on a color wheel? Why?
- Why do we use the L*a*b* color system as opposed to the others?
- When do we calibrate our instrument?
- When do we recalibrate on another (non-white) plate and why?
- What are our Instrument Standard Conditions and why do we use these?
- What would be the expected Delta E range expected from two paint samples from the same source (samples from the same area in excellent condition)?
- What is the "Reference" sample in our analysis scheme? How is it chosen
- Define the following instrumental terms:
  - INDEX SET
  - TARGET COLOR SELECT
  - COLOR SPACE SELECT
  - DISPLAY PRINT
  - COLOR SPACE
  - ABS. /DIFF.
  - CALIBRATE
  - STATISTIC (both types)
  - PAGE
  - MEASURE
  - AUTOSELECT
- Why might a pink paint sample be closer to the White Cal plate than the Red Cal plate?
- How and when should the Calibration Plates be cleaned?
- What is specular light?
- What is the minimum sample diameter (mm) required?
- Why are the original and a photocopy of the data printouts given to the examiner requesting the support work?

5.4.4 Practical Exercises

5.4.4.1 The trainee will become familiar with the instrument by comparing measurements from the same source and from different sources. **Caution!! Do not erase or change values in TARGET SETS 00 through 09.**

5.4.4.2.1 After starting a fresh "Page", place the measuring device in the locked position onto the White calibration plate and measure 10 times in the ABSOLUTE MEASUREMENT mode. Use the Measure Button on the Data Processor instead of the one on the measuring head so that the sampling area stays exactly the same). Run the statistics. Repeat for the Red calibration plate. Repeat for something that has multiple colors (heterogeneous) in the measuring area. Repeat for White and Red plates but change locations of sampling for every measurement.

5.4.4.2 Using the Reference Collection of Automotive Paints from Collaborative Testing Services, Inc, the trainee will:

5.4.4.2.1 Sample (10 times each) three nonmetallic paints and three metallic paints (fine, medium and course) using the colorimeter.

5.4.4.2.2 Find various nonmetallic colors that match/nearly match with the unaided eye and compare these using the colorimeter.

5.4.4.2.3 Choose a white nonmetallic as a "reference" target. Compare (Delta E) with other white paints and observe and record the unaided eye comparisons for various Delta E differences. Repeat for red, green, blue and yellow.

5.4.4.3 The trainee will determine Delta E differences for the Macbeth Daylighting Metamerism Test Kits #2 and #3.

5.4.4.4 The trainee will observe and record Delta E differences between adjacent color chips in the Munsell Book of Color.

5.4.4.5 The trainee will obtain an automotive paint chip in excellent condition. This paint chip will be broken in half and will be analyzed with the colorimeter. Record colorimetry results between the "comparison" sample and the "reference" sample after various stages of scratching the surface of the comparison chip with sand paper. Begin with a slight scratching of the surface and continue to heavy scratching of the surface.

5.5 Evaluation

5.5.1 The trainer will review the written answers to the questions with the trainee.

5.5.2 The trainer and the trainee will review and discuss the pertinent points of each of the required readings.

5.5.3 Review of practical exercises.

5.6 Forensic Significance of Colorimetry Results

5.6.1 Objectives

Through completion of this module the trainee will have developed and demonstrated theoretical knowledge and/or practical skills to:

- Compare samples with accuracy and precision;
- Correctly interpret comparison data, take notes and issue written instrument support reports; and
- Articulate results and related matters to other examiners and court personnel.

5.6.2 Questions

The trainee will provide written answers to the following questions:

- What Delta E value is considered to be a "match/consistent", "similar" and "could not be associated"? Explain in detail.
- List pros and cons of color comparisons with the unaided eye vs. the CR-221.
- Why not provide "data only" to the examiner requesting the Colorimeter support?
- List the pros and cons of CR-221 tristimulus colorimetry comparisons vs. microspectrophotometry spectral comparisons.
- Explain Delta E in scientific terms and in layman's terms.

5.6.3 Practical Exercises

5.6.3.1 The trainee will be provided with copies of past Colorimetry Instrument Support results for review.

5.6.3.2 The trainee will complete a minimum of 5 sets of unknown test samples.

5.6.3.3 The trainer will discuss court testimony with the trainee in regards to Colorimetry Support analysis.

5.6.3.4 The trainee will observe all case related colorimetry analyses conducted during the training period, as possible.

5.6.4 Evaluation

5.6.4.1 The trainer will review the written answers to the questions with the trainee.

5.6.4.2 Review of practical exercises.

5.7 Reading List

5.7.1 Billmeyer, Fred W., Jr., Principals of Color Technology, 2nd Ed., John Wiley & Sons, New York, 1981

5.7.2 Cousins, D. R., "The Use of Microspectrophotometry in the Examination of Paints", Forensic Science Review, Vol. 1, No. 2, Dec. 1989, pp.142-162.

5.7.3 Fouweather, C., May, R. W., and Porter, J., "The Application of a Standard Color Coding System to Paint in Forensic Science", Journal of Forensic Science, Vol. 20, 1976, pp.629-635.

5.7.4 HunterLab publication GC 2.0.1, 11/90, The Science and Technology of Appearance Measurement.

5.7.5 HunterLab publication GC 2.2 8.5K, 8/87, Analyzing Appearance by Measurements.

5.7.6 Locke, J., Cousins, D. R., Russell, L. W., Jenkins, C. M., and Wilkinson, J. M., "A Data Collection of Vehicle Topcoat Colours. 1. Instrumentation for Colour Measurements", Forensic Science International, Vol. 34, 1987, pp.131-142.

5.7.7 Macbeth, brochure, "SpectraLight® Color Matching Booths and Luminaries", no date.

5.7.8 Macbeth/Munsell publication 7m JUL 90, Munsell Color (Munsell Color Space)

5.7.9 Macbeth/Munsell written pages in the front of the R-G volume of the Munsell Book of Color (Glossy Finish Collection Removable Samples in Two Binders), Macbeth Division of Kollmorgen Instruments Corporation, Baltimore, Maryland.

5.7.10 Minolta publication PCC 410-B2, Precise Color Communication, Minolta Camera Co., Ltd., Japan, no date.

5.7.11 Minolta Corp. Japan, Manuals, "CHROMA METER CR-200 CR-231" ver. 2.0, 9222-1849-41 P802-B2, 1987; "CHROMA METER CR-221" (supplement) 9222-1849-31 P710-A1, 1987 with "SHORT FORM INSTRUCTIONS FOR NEW DATA PROCESSOR" insert; "COLOR CALIBRATION PLATE" (nine plate set) 9223-1849-78 P708-A1, Minolta Camera Co., Ltd., Japan, 1987.

5.7.12 Willard, Hobart H., Merritt, Lynne L., Dean, John A. and Settle, Frank A. Jr., Instrumental Methods of Analysis, Sixth Ed., Wadsworth Publishing Company, Belmont California.

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